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*THE MISUSE OF PHYSICS BY BIOLOGISTS AND ENGINEERS.**

THIS somewhat informal paper is preliminary to a paper which I have in preparation on statistical physics. My chief object in presenting this preliminary paper is to call attention to some of the precise notions of thermodynamics and to point out the essential limitations of that subject. Gibbs, for example, raises the question repeatedly in his writings as to the legitimacy of the thermodynamic discussion of things, such as thermoelectricity, which are associated necessarily with irreversible processes. What I have in mind concerning thermodynamics proper and concerning statistical physics is a general point of view which completely elucidates this question of Gibbs, setting precise limits not only to systematic thermodynamics, but to systematic physics in the broadest sense, and marking sharp boundaries between systematic physics and what we may call statistical physics.

A great deal is, I think, to be gained for science at the present time by insisting upon the sharp delimitation of those general ideas in physics which are related primarily to thermodynamics just as a great deal has been gained in the last half century by the sharp delimitation of those general ideas which relate primarily to

* A paper read before the American Physical Society on October 31, 1903.

mechanics. There is, I think, a widespread confusion of boundaries which makes this sharp delimitation a thing greatly to be desired, and I have chosen as the title of this preliminary paper 'The Misuse of Physics by Biologists and Engineers' for the reason that, in my opinion, these men, more than any others, violate in their philosophy the essential limitations of systematic physics and confuse the boundaries between systematic physics and statistical physics.

I do not wish this title to be taken as a challenge to biologists and engineers, but rather as suggesting, in a general way, the error of the indiscriminate application of the philosophy of the exact sciences in the study of natural phenomena. I do not expect, indeed, to make my position entirely clear until I have finished with what I have to say about statistical physics, but my position in brief is this, that the idea of quantitative relationships and the idea of one-to-one correspondence in general, as these ideas are known in physics, are inapplicable and necessarily fruitless in such fields as physical psychology and meteorology.

I am led to present this preliminary paper at this time from having read the recent presidential address of James Swinburne before the British Institution of Electrical Engineers and a subsequent paper on thermodynamics presented by Mr. Swinburne at the Southport meeting of the British Association in September.

Mr. Swinburne believes, apparently, that the precise ideas and methods of thermodynamics are unconditionally applicable to irreversible processes in general. I do not agree with him in this, and I do not think that the legitimacy and precision of the accepted ideas of thermodynamics especially as represented in the writings of Willard Gibbs can be questioned; but I do think that the notions of thermodynamics are precisely applicable to those types of irreversible processes which constitute permanently varying states, and approximately applicable to those irreversible processes which involve either approximate states of thermal equilibrium or approximately permanent states of variation. I shall point out the precise application of the ideas of thermodynamics to permanently varying states in this preliminary paper, reserving the discussion of approximate applications for a subsequent paper.

The fact is that the precise notions of systematic physics in general are essentially inapplicable in the world of actual phenomena, except in so far as these phenomena can be approximately correlated to *states of equilibrium* and to *permanently varying states* of material systems. I remember very distinctly the incredulity with which I first encountered, in my early study of physics, the unguardedly sweeping generalizations in the treatises which I then read, for example, on the elementary mathematical theory of electricity and magnetism. I could not believe that the phenomena of electricity and magnetism were quantitative in the sense that my then highly abstracted ideas of mechanical phenomena were quantitative.

In order to give some sort of a preliminary notion of what I have in mind in using the terms systematic physics and statistical physics I shall resort to classification.

Physics is divided into two branches, namely, systematic physics and statistical physics.

Systematic physics is again divided into mechanics and thermodynamics.

Mechanics, in the broad sense here defined, treats of those phenomena which can be to a high degree of approximation correlated in one-to-one correspondences to states of equilibrium and to simple types of sensible motion such as translatory mo-

tion, rotatory motion, motion involved in simple types of elastic distortion, steady types of fluid motion including wave motion and the corresponding types of force action. This definition of mechanics includes a large portion of the subjects of electricity and magnetism and of light. Mechanics, as here defined, includes all phenomena which involve action between bodies and regions of finite size, which action can be perceived directly or indirectly as a unit.

Thermodynamics treats of those phenomena which can be to a high degree of approximation correlated in one-to-one correspondences to states and processes involving thermal equilibrium and involving those permanently varying states which I have called steady sweeps. Thermodynamics involves much mechanics, but mechanics proper ignores everything which pertains strictly to thermodynamics. Thermodynamics includes all portions of the subjects of electricity and magnetism and light which are not completely defined in mechanical terms.

Statistical physics is the study of all the actual physical phenomena of nature, some of which, indeed, may be described in terms of the notions of ideal mechanics to a high degree of approximation, and some of which, indeed, may be described in terms of the notions of ideal thermodynamics to a high degree of approximation, but all of which are more or less erratic and in their minute details infinitely manifold, and in all of which the notion of one-to-one correspondence or of cause and effect, if one prefers that mode of expression, fails.

A clear understanding of the essential limitations of systematic physics is important to the engineer; it is, I think, equally important to the biologist, and it is of vital importance to the physicist, for in the case of the physicist, to raise the question as to limitations is to raise the question as to whether his science does after all deal with realities, and the conclusion which must force itself on his mind is, I think, that his science, the systematic part of it, comes very near, indeed, to being a science of unrealities. This is not necessarily to the discredit of the physicist, provided he knows it.

The engineer is not far wrong in his application of the principles of mechanics, for the engineer is chiefly concerned with integral relationships between finite things. Nevertheless, I think that the engineer frequently attempts to carry his mechanics too far, when, for example, he attempts anything but the crudest correlation in his studies of such things as friction and fluid motion. The phenomena of friction and of fluid motion can not be correlated—I do not mean by human means, conditionally as it were, but I mean that they absolutely can not be approximately correlated by any means in one-to-one correspondences. I discussed this matter briefly in some remarks before the American Institute of Electrical Engineers on December 19, 1902.* In studies which require the application of the principles of thermodynamics, on the other hand, engineers are, I think, frequently in error. Thus, Mr. Swinburne's difficulty—his statements, being partly right and partly wrong, may be taken to indicate a difficulty—seems to me to lie in an improper application of the principles of thermodynamics.

The biologist, on the other hand, is, I think, usually illogical when he attempts to make use of the ideas of systematic physics. The biological sciences, in so far as they are related to systematic physics at all, are related primarily to thermodynamics, and in so far as the biologist is unfamiliar with the principles of thermodynamics he can not make proper use of

* See *Trans. A. I. E. E.*, January, 1903, pp. 79–80.

any of the generalizations of systematic physics. I shall consider later the relations of biology and statistical physics, not, of course, from the point of view of the biologist, for this would be to discuss the relation of organism to environment, but in the light of some of the ideas of thermodynamics.

The biologist and the engineer need to have precise knowledge of thermodynamics, inasmuch as it is thermodynamics chiefly which determines the limits of correct application of the ideas and methods of systematic physics to natural phenomena.

This subject of thermodynamics is so little understood that I am not willing to proceed to a precise discussion of the questions set forth in a general way above, without first giving an outline of the fundamental ideas of thermodynamics, which I shall give as concisely and concretely as possible. I feel justified in taking your time in this way for the reason that here and there throughout my presentation you will find that the ideas are new, and, furthermore, I wish this paper to be readable by biologists and engineers.

In some instances I shall insist upon what may seem to be unnecessarily fine distinctions; but Whewell says very aptly that 'In order to acquire any exact solid knowledge the student must possess with perfect precision the ideas appropriate to that part of knowledge.' If there is any branch of physics where perfect precision of ideas is demanded it is, I think, in the subject of thermodynamics, especially if the boundaries between the legitimate realm of thermodynamics and the almost untouched realm of statistical physics are to be sharply defined.

Perfect precision of ideas is tested, as Whewell says, by the extent to which one perceives axiomatic evidence in a subject, and I give this sketch of thermodynamics exactly with the view of setting forth axiomatic evidences.

1. THERMAL EQUILIBRIUM.

When a substance is shielded from outside disturbance it settles to a state in which there is no tendency to further change of any kind. Such a state is called a state of *thermal equilibrium.*

When a substance has settled to thermal equilibrium it is said to have a definite temperature. The notion of temperature, that is the precise idea of temperature, as a physical fact is derived from the notion of thermal equilibrium. Also the idea of differences of temperature as physical facts (not as quantities) is derived from comparisons of states of thermal equilibrium.

The idea of thermal equilibrium applies to a limit which is never realized. It is impracticable to shield a substance completely. Failure of two kinds occurs, namely, failure to prevent exchange of energy between one system and another, either in the form of mechanical work or in the form of heat, and failure to prevent exchange of matter between one system and another. This second failure is very marked in the case of radioactive substances. Furthermore, our accepted notions as to the quickness with which a gas, for instance, settles to thermal equilibrium may be altogether wrong, for Boltzmann has pointed out that even a small mass of gas shielded completely in a vessel may, for all we know, require months to settle to anything approaching complete thermal equilibrium.

Before proceeding with this outline of thermodynamics I wish to state what is my opinion as to the influence which the kinetic theory (of gases) is destined to have upon the subject of thermodynamics. Several years ago, in writing a review of Duhem's elaborate mathematical development of thermodynamics, 'Mechanique Chemique,'

I contrasted the purely sensible basis and the abstract but inevitable mathematical structure of thermodynamics, on the one hand, with the mathematical theory of electricity and magnetism as it stands in Maxwell's 'Treatise,' on the other hand. Maxwell's theory is, of course, largely based on sensible things, but sensible things which are more or less inadequate to determine the essential elements of the theory, so that conception enters as an important and vital part of the theory. I stated that perhaps we are to have in thermodynamics a branch of physics which is to remain independent of conceptions, to remain, in other words, a purely algebraic structure resting upon an adequate foundation of axiomatic evidence which may be directly perceived. I do not now think that this is to be the case, but I think that the ideas of the kinetic theory, or, as Gibbs puts it, the ideas of statistical mechanics, are destined to become vital in the subject of thermodynamics; and I think that it is of the greatest importance in the treatment of thermodynamics, to reach conceptions of every fundamental notion with the help of the kinetic theory (statistical mechanics).

In view of my opinion as to the vital importance of statistical mechanics in thermodynamics, I shall suggest, whenever I can do so briefly, the molecular conceptions of the various notions of thermodynamics.

The Molecular Conception of Thermal Equilibrium.—The molecular motion at a given point in a gas (and no doubt in any substance) in thermal equilibrium is entirely erratic; an irregular and extremely rapid succession of fits and starts occurs as the molecules collide against each other, and the character of the molecular motion at the point is still further complicated by the fact that different molecules are continually passing the given point from every direction and with every variety of speed and oscillatory motion. Because of the enormous number of molecules in any perceptible volume of a substance it is the *average character* of the molecular motion, only, which has to do with temperature and pressure and in general with all thermal properties of substances; and, because of the enormous number of molecules, this average character of molecular motion is constant and uniform throughout a substance when the substance is in thermal equilibrium.

2. REVERSIBLE PROCESSES.

A substance in thermal equilibrium is generally under the influence of external agencies. Thus, surrounding substances confine the given substance to a certain region of space and they exert upon the given substance a constant pressure; surrounding substances are at the same temperature as the given substance and the molecules of the given substance rebound from surrounding substances with their motion, on the average, unchanged; surrounding substances may exert constant magnetic or electric influences upon the given substance, and so on. However, a substance can not be in thermal equilibrium when work is continually done upon or done by it, or when heat is continually given to or taken from it.

If the external influences which act upon a fluid in thermal equilibrium are made to change *very slowly*, causing the pressure and volume of the fluid to pass very slowly through a continuous series of values and in general involving the doing of work upon or by the fluid and the giving of heat to or taking of heat from the fluid, the fluid will pass slowly through *a process consisting of a continuous series of states of thermal equilibrium*. Such a process is called a *reversible process*, for the reason that the fluid will pass through the same

series of states in reverse order if the external influences are changed slowly so as to make the pressure and volume of the fluid pass through the same series of values in reverse order.

The characteristics of a reversible process are therefore as follows:

(*a*) A substance which undergoes a reversible process must be under varying *external* influence. A closed system can not perform a reversible process.

(*b*) A substance as it undergoes a reversible process is at each instant in a state of thermal equilibrium; and if, at a given instant during a reversible process, the external influences should cease to change, causing a sudden cessation of the doing of work on or by the substance, and of the interchange of heat between the substance and its surroundings, no commotion would be left in the substance.

(*c*) A reversible process must take place slowly, strictly with infinite slowness. An actual process, that is, a process which actually does proceed, can be only approximately reversible. Examples of reversible processes are given in the article on trailing sweeps, for it is important that it be clearly recognized that a reversible process is the limit which a trailing sweep approaches when it is performed more and more slowly.

3. SWEEPING OR IRREVERSIBLE PROCESSES.

While a substance is settling or tending to settle to thermal equilibrium it may be said to undergo a process. Such a process can not, in general, be arrested and maintained at any stage short of complete thermal equilibrium, but always and inevitably proceeds towards that state. Such a process is, therefore, called a *sweeping process* or simply a *sweep*.

A sweeping process takes place in one direction only, that is, if A and B are two successive stages of a sweep, stage B following stage A, then stage B grows out of stage A inevitably, but stage A can not be made to follow or grow out of stage B by any means whatever. A sweeping process, therefore, is irreversible.

Molecular Conception of the Sweeping Process.—While a gas (and perhaps any substance) is settling to thermal equilibrium, immediately after an explosion, for example, the character of the molecular motion at a given point changes rapidly from instant to instant and the character of the molecular motion at a given instant varies greatly from point to point in the gas; in other words, the gas is the seat of more or less violent turbulence while it is settling to thermal equilibrium.

The effects of mutual collision among the molecules, the effects of the collision of the molecules against the walls of the containing vessel and the effects of the confused movement* of the gas molecules from one part of the vessel to another part are always to even up the differences in the character of molecular motion in different parts of the vessel. On the other hand, the external influences which can be brought to bear on a substance act on all the molecules in the same general way, so that the tendency of a turbulent state of a gas to die away on account of the internal actions just pointed out can not be counteracted by external influences,† and,

* If a great number of white and black balls are placed in a box and shaken up, the confused motion tends to cause an even distribution of white and black balls throughout the box, for the reason that, of all possible arrangements of the balls, approximately even distribution is the most probable.

† The maintenance of an unending state of turbulence in a trailing sweep because of rapidly changing external influence is by no means a case in which the tendency of a turbulent state to die away is counteracted by external action, but rather a case in which the goal, namely the final state of thermal equilibrium, is made to recede continuously.

therefore, a sweeping process can not be arrested nor reversed by any means.

Note 1.—A fluid not in thermal equilibrium has no definite pressure, temperature or volume. The volume of a turbulent gas pertains only to the containing vessel. Any one, for example, who reads the reports of the measurement of the Holton and St. Albans base lines by the U. S. Coast and Geodetic Survey will appreciate the necessity of the projection of a region of thermal equilibrium into a space which is to be measured, and any one of course knows that the reality of the results of these measurements depends upon the fact that the earth's crust is approximately in thermal equilibrium.

One error in Mr. Swinburne's discussion of thermodynamics is in the extension of the notions of volume, pressure, temperature and entropy to substances not in thermal equilibrium. Points in Watt's diagram can represent only states of equilibrium, and lines in Watt's diagram can represent only reversible processes. I shall indicate in a subsequent paper the method which must be used when one wishes to extend engine calculations, for example, so as to include sweeping processes.

Note 2.—Writers on thermodynamics who are obliged to deal with irreversible processes or sweeping processes, that is to say, steam engineers, frequently introduce the notion of the integration of entropy and temperature. Thus Mr. Swinburne enlarges upon this procedure. He would assign a definite entropy and a definite temperature to each volume element of turbulent steam, and by integration arrive at the notion of total entropy and mean temperature. Now in the first place, when this method appears to give results a legitimate mode of calculating sweeps is really used, and the legitimate ideas involved are illogically expressed in terms of temperature and entropy. In the second place, *temperature and entropy have no meaning as applied to the elements of volume, even of a substance in thermal equilibrium,* not to mention the question of their application to the volume elements of a turbulent substance. This is a limitation of the ideas of thermodynamics which is indicated by the ideas of statistical mechanics. Whether this limitation can be justified independently of statistical mechanics I am not prepared to say with certainty. Thermodynamics has to do only with finite portions of matter, and infinitesimals have no meaning except as increments of finite quantities.

4. SIMPLE SWEEPS.

The settling of a closed system to thermal equilibrium is called a *simple sweep.*

Example.—The equilibrium of a mixture of oxygen and hydrogen in a closed vessel may be disturbed by a minute spark, and the explosion and subsequent settling of the aqueous vapor to a quiescent state without loss of heat constitute a simple sweep. The equilibrium of a gas confined under high pressure in one half of a two-chambered vessel may be disturbed by opening a cock which connects the two chambers, and the rush of gas into the empty chamber constitutes a simple sweep.

5. TRAILING SWEEPS.

When external influences change continuously, a substance in its tendency to settle to equilibrium never catches up, as it were, with the changing conditions, but trails along behind them, and we have what is called a *trailing sweep.*

Examples.—The rapid expansion or compression of a gas in a cylinder is a trailing sweep. So long as the piston moves at a perceptible speed, the gas, in its tendency to settle to equilibrium, never catches up with the varying conditions. This is evi-

dent, for any one can see that a sudden stoppage of the piston would leave some slight turbulence in the gas, which would not be the case if the gas were in equilibrium at the instant the piston is stopped. When the piston is moved more and more slowly, the departure of the gas from strict thermal equilibrium at each stage of the expansion or compression becomes less and less, and the expansion or compression approaches more and more nearly to a reversible process.

The rapid heating (or cooling) of a gas in a closed vessel is a trailing sweep. So long as heat is given to the gas at a perceptible rate there will be perceptible differences of temperature in different parts of the gas; the gas in its tendency to settle to thermal equilibrium never catches up with the increasing temperature of the walls of the containing vessel.

When the gas is heated (or cooled) more and more slowly, that is, when heat is given to the gas at a rate which becomes more and more nearly imperceptible, then the departure of the gas from strict thermal equilibrium at each stage of the heating process becomes less and less, and the heating (or cooling) approaches more and more nearly to a reversible process.

6. STEADY SWEEPS.

A substance may be subjected to external action which, although unvarying, is incompatible with thermal equilibrium. When such is the case the substance settles to a permanent or unvarying state which is not a state of thermal equilibrium. Such a state of a substance is called a *steady sweep*.

Examples.—The two faces of a slab or the two ends of a wire may be kept permanently at different temperatures. When this is done the slab or wire settles to an unvarying state which is by no means a state of thermal equilibrium. Heat flows through the slab or along the wire from the region of high temperature to the region of low temperature, *never* from the region of low temperature to the region of high temperature. This flow of heat through the slab or along the wire is an irreversible process and it constitutes a steady sweep.

The ends of a wire may be kept permanently at different electric pressures, for example, by connecting the wire to the terminals of a battery or dynamo. When this is done a steady electric current flows along the wire, the battery does work steadily on the wire, and this work reappears steadily as heat in the wire. Reversal of the current *does not* reverse this process and cause heat energy to disappear in the wire (cooling the wire) and reappear as work done on the battery by the wire, but the process is irreversible and it constitutes a steady sweep.

The notion of steady sweeps is of the utmost importance in thermodynamics inasmuch as thermodynamics treats directly of states of thermal equilibrium and of steady sweeps only.

The notion of entropy is involved in the notion of a steady sweep; and the notion of temperature is involved in the notion of thermal equilibrium.

7. THERMODYNAMIC DEGENERATION AND REGENERATION.

A sweeping process always plays a certain havoc, or effects a certain *degeneration* in a system. Thus, there is a certain degeneration associated with the escape of a compressed gas through an orifice; there is a certain degeneration associated with the flow of heat from a region of high temperature to a region of low temperature; there is a certain degeneration associated with the direct conversion of work into heat, and so on.

In a simple sweep the degeneration lies wholly in the relation between the

initial and final states of the substance which undergoes the sweep, inasmuch as, in a simple sweep, no outside substance is affected in any way, no work is done on or by the substance which undergoes the sweep, and no heat is given to or taken from it.

In a trailing sweep the degeneration may lie partly in the relation between the initial and final states of the substance which undegoes the sweep, partly in the direct conversion of work into heat and partly in the direct transfer of heat from regions of high temperature to regions of low temperature.

In a steady sweep the substance which undergoes the sweep remains entirely unchanged as the sweep proceeds, and the degeneration lies wholly in the direct conversion of work into heat, in the direct transfer of heat from a region of high temperature to a region of low temperature, or both.

A substance which has undergone a sweeping process may be brought back to its initial state, or *regenerated,* by a reversible process; but when a substance is regenerated by a reversible process, the external action necessary to bring about the reversible process involves an equal degeneration of some external substance; that is, the regeneration of a substance by a reversible process always involves the creation of an equal external regeneration. This is, in fact, a statement of the second law of thermodynamics.

The entire subject of thermodynamics, in so far as it does not have to do with the specific thermal properties of particular substances, is based upon the consideration of the two kinds of thermodynamic degeneration which are involved in steady sweeps, that is, upon: (*a*) The thermodynamic degeneration which is represented by the direct conversion of work into heat, and the thermodynamic regeneration which is represented by the conversion of work into heat by a reversible process; and (*b*) The thermodynamic degeneration which is represented by the direct transfer of heat from a region of high temperature to a region of low temperature, and the thermodynamic regeneration which is represented by the transfer of heat from a low temperature region to a high temperature region by a reversible process.

The following two propositions concerning the two kinds of thermodynamic degeneration (*a*) and (*b*) follow at once from a consideration of steady sweeps.

PROPOSITION (A).—The thermodynamic degeneration represented by the direct conversion of work into heat at a given temperature is *proportional* to the quantity of work so converted.

Proof.—Consider a steady flow of electric current in a wire. This process being steady, the amount of degeneration occurring in a given interval of time must be proportional to the time. The amount of work converted into heat is also proportional to the time. Therefore the amount of degeneration is proportional to the amount of work converted into heat. Of course the temperature must be invariable, or the process can not be thought of as remaining identically the same from instant to instant. The dependence of this kind of degeneration upon temperature will be considered later.

Corollary.—The thermodynamic regeneration which is represented by the conversion of heat at a given temperature into work by a reversible process is proportional to the heat so converted.

PROPOSITION (B).—The thermodynamic degeneration represented by the direct transfer of heat from a given high temperature T_1 to a given low temperature T_2 is proportional to the quantity of heat transferred.

Proof.—Consider a steady flow of heat

from temperature T_1 to temperature T_2 constituting a steady sweep. This process being steady, the degeneration occurring in a given interval of time must be proportional to the time. The quantity of heat transferred is also proportional to the time. Therefore, the amount of degeneration is proportional to the quantity of heat transferred. The dependence of this kind of degeneration upon temperature will be considered later.

Corollary.—The thermodynamic regeneration which is represented by the transfer of heat from a low temperature T_2 to a high temperature T_1 by a reversible process is proportional to the heat transferred.

8. THE SECOND LAW OF THERMODYNAMICS.

(*a*) The degeneration of a system which accompanies a sweeping process can not be directly repaired, nor can it be repaired by any means without the creation of a compensating degeneration in some other system.

This is an entirely general statement of the second law. The *direct repair* of the degeneration due to a sweeping process means the undoing of the havoc wrought by the sweep by allowing the sweep to *perform itself backwards!* This notion of *direct repair* is introduced into this general statement of the second law in order that each of the following particular statements of the law, namely, (*b*), (*c*) and (*d*) may correspond exactly in form to the general statement (*a*). A slightly modified general statement of the second law is the following:

(*a*) Thermodynamic degeneration and regeneration are always balanced in a reversible process, while degeneration always exceeds regeneration in any process which is in any way sweeping in character.

(*b*) Heat can not pass directly from a cold body to a hot body, nor can heat be transferred from a cold body to a hot body by any means without compensation.

(*c*) Heat can not be converted directly into work, nor can heat be converted into work by any means without compensation.

The direct conversion of heat into work (see discussion following (*a*) above) would be simply the reverse of any of the ordinary sweeping processes which involve the degeneration of work into heat. Thus, work is degenerated into heat in the bearing of a rotating shaft, and we all know that to reverse the motion of the shaft will not cause the bearing to grow cold and the heat so lost to appear as work helping to turn the shaft!

(*d*) A gas can not pass directly from a region of low pressure to a region of high pressure, nor can a gas be transferred from a region of low pressure to a region of high pressure by any means without compensation.

The compensation involved in the transfer of a gas from a region of low pressure to a region of high pressure by means of a pump is the degeneration into heat of the work spent in driving the pump.

The repeated statement of self-evident facts in these statements of the second law of thermodynamics may seem ridiculous to the intelligent reader, but it must be remembered that but few persons realize that the second law of thermodynamics is a statement of a fact which every one knows, together with a generalizing clause which when once thoroughly understood is almost if not quite self-evident. I can not refrain from one more statement of the second law, the oldest English version of it:

Humpty Dumpty sat on a wall.
Humpty Dumpty had a great fall.
All the King's horses and all the King's men
Can not put Humpty Dumpty together again.

This is perhaps the most dignified of all the statements of the second law of thermodynamics, inasmuch as it omits all nonsense about *direct repair* and refers at once to external means.

The reader must not imagine, however, that thermodynamic degeneration has anything to do with structural degeneration or dissolution, which is the most prominent feature of the calamity which befell Humpty Dumpty, but, to put the case concretely, if one shakes up a quantity of pure and homogeneous water in a bottle, one plays that irreparable havoc which constitutes thermodynamic degeneration.

9. ENGINES.

The further development of the subject of thermodynamics depends upon the establishment of the exact relation between the degeneration which is represented by the transfer of heat from a high to a low temperature and the degeneration which is represented by the conversion of work into heat. To establish this relation it is necessary to consider a *reversible process* in which the degeneration of heat from high to low temperature is compensated by the regeneration of heat into work, or *vice versa.*

The engine is a machine which determines such a process. The ordinary engine, indeed, is subject to friction, and the steam as it passes through the engine does not undergo a reversible process; but if the engine were frictionless, if it were driven slowly, if the cylinder were prevented from cooling the steam, if the steam were expanded sufficiently to prevent puffing and if the feed water were heated, in a 'regenerative' feed water heater, to boiler temperature before entering the boiler, then the processes involved in the operation of the engine would be reversible. Such an ideal engine we will call a *reversible engine* or a *perfect engine.*

During a given interval of time the engine takes an amount of heat H_1 from the boiler at temperature T_1, it converts into work W a certain fractional part of H_1 and delivers the remainder H_2 to the condenser at temperature T_2.

The work W done by the engine is equal to the difference $H_1 - H_2$ according to the first law of thermodynamics. That is,

$$W = H_1 - H_2. \tag{1}$$

Now, all the heat used in the engine comes from the region at temperature T_1, and the net result of the operation of the engine is: (a) to convert the quantity $W(=H_1 - H_2)$ of heat from temperature T_1 into work, and (b) to transfer the quantity H_2 of heat from temperature T_1 to temperature T_2. The result (a) involves an amount of regeneration which is proportional to W, temperature being given; this regeneration may, therefore, be represented by mW where m is a constant depending *only* on the temperature T_1. The result (b) involves an amount of degeneration which is proportional to H_2, temperatures being given; this degeneration may, therefore, be represented by nH_2 where n is a constant depending *only* on the temperatures T_1 and T_2. If the engine is reversible we must have

$$mW = nH_2, \tag{2)a}$$

or, using the value $(H_1 - W)$ for H_2, and solving for W we have

$$W = \frac{n}{m+n} H_1, \tag{2)b}$$

in which $n/(m+n)$ depends on T_1 and T_2, *only,* irrespective of the kind of engine and of the physical properties of the fluid employed in the engine, provided, only, that the engine is reversible. The fractional part $n/(m+n)$ of the heat H_1 which the engine converts into work is called the efficiency of the engine, and from equation (2)b it follows that *the efficiency of all reversible engines is the same for given values of the temperatures* T_1 *and* T_2.

If the operation of the engine involves sweeping processes of any kind then the degeneration nH_2 exceeds the regeneration mW or

$$mW < nH_2,$$

or, using the value $(H_1 - W)$ for H_2, and solving for W we have

$$W < \frac{n}{m+n} H_1, \tag{3}$$

in which m and n have the same values as in equation (1). Comparing this with equation (2)b it follows that *any irreversible engine working between given temperatures T_1 and T_2 has less efficiency than a reversible engine working between the same temperatures.*

10. THERMODYNAMIC DEFINITION OF THE RATIO OF TWO TEMPERATURES.

According to article 9 the ratio, H_1/H_2, of the heat taken from the boiler to the heat given to the condenser by any reversible engine working between the given temperatures T_1 and T_2 is invariable, and it can be easily shown that this ratio approaches unity as T_1 and T_2 approach equality. Therefore, the ratio of the two temperatures T_1/T_2 may be defined as the ratio of the two heats H_1/H_2. That is:

$$\frac{T_1}{T_2} = \frac{H_1}{H_2}. \tag{4}$$

11. ENTROPY. THERMODYNAMIC DEGENERATION.

The statement of the second law of thermodynamics can scarcely be looked upon as complete until a precise and complete numerical measure of thermodynamic degeneration has been established. This numerical measure of thermodynamic degeneration is called entropy. The notion of entropy may be completely developed by consideration of steady sweeps. I will give this development first and I will give Clausius's development afterwards in order to point out an error in Clausius's discussion.

Referring to article 9 we may write the expression for the regeneration mW in the form $f(T_1) \cdot W$ inasmuch as m is a function of T_1 only.

The degeneration nH_2 may be written

$$[f(T_2) - f(T_1)]H_2,$$

inasmuch as the degeneration associated with the transfer of the heat H_2 from T_1 to T_2 may be thought of as (a) the regeneration of H_2 from temperature T_1 to work, and (b) the degeneration of this resulting work to heat at temperature T_2; in which case the regeneration (a) is $f(T_1) \cdot H_2$ and the degeneration (b) is $f(T_2) \cdot H_2$.

Therefore, equation (2)a may be written

$$f(T_1) \cdot W = [f(T_2) - f(T_1)]H_2.$$

Using equation (1) and equation (4) we have

$$\frac{f(T_2) - f(T_1)}{f(T_1)} = \frac{T_1 - T_2}{T_2}.$$

From which the function f is to be determined. Differentiating with respect to T_2 we have

$$\frac{f'(T_2)}{f(T_1)} = -\frac{T_1}{T_2^2} = -\frac{\frac{1}{T_2^2}}{\frac{1}{T_1}};$$

and, therefore, since T_1 and T_2 are independent of each other we have

$$f(T_1) = \frac{1}{T_1}.$$

That is to say, the thermodynamic degeneration associated with the conversion of an amount of work W into heat at temperature T_1 is equal to W/T_1, and the thermodynamic degeneration associated with the transfer of an amount of heat H_2 from temperature T_1 to temperature T_2 is

$$\frac{H_2}{T_2} - \frac{H_2}{T_1}.$$

Clausius's derivation of the numerical measure of entropy is based upon the idea that degeneration and regeneration are balanced in a reversible process. In this derivation it is necessary to consider a cyclic process (reversible) in order that no outstanding change of state may be left as a result of the process, so that one need consider only the exchange of work and heat between the substance which is being studied and external substances, and in particular one is not under the necessity of considering the amount of degeneration or regeneration involved in the change of state of a particular substance.

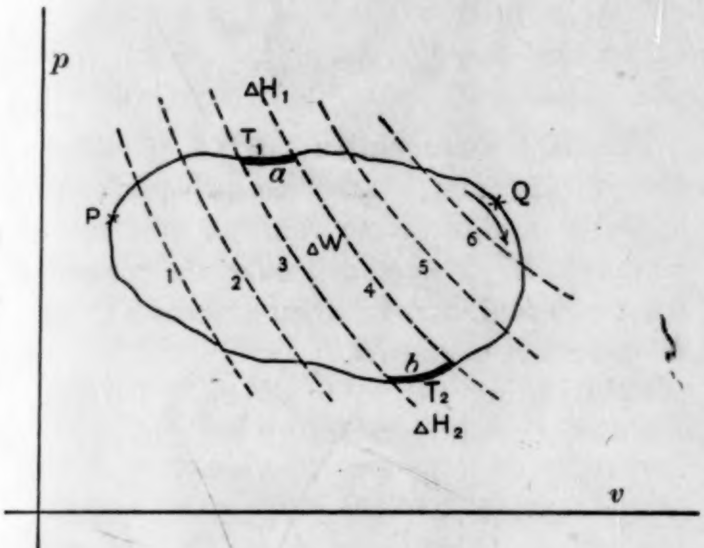

FIG. 1.

Consider a fluid, which, starting from the state P, Fig. 1, is made to pass through a reversible cyclic process and return to the state P by any combination whatever of slow heating and cooling, expanding and compressing. The closed curve represents the cyclic process, and the moving point Q as it moves along the process curve represents the changing state of the fluid.

A clear idea of the external actions which take place may be obtained by drawing a series of adiabatic or isentropic lines (an isentropic line represents the variation of pressure with volume when the fluid neither gives off nor receives heat). The fluid is receiving heat while Q is crossing isentropic lines from small numbers to large numbers in Fig. 1, and giving off heat while Q is crossing isentropic lines from large numbers to small numbers. The fluid is expanding and doing external work when Q is moving to the right, and contracting and having work done upon it when Q is moving to the left. The fluid is in general at high temperature for those positions of Q where p and v are both large, and at low temperatures for those positions of Q where p and v are both small.

Consider two portions, a and b, of the given process curve which lie between a pair of isentropic lines. Let T_1 be the high temperature of the fluid when Q is passing along a, and let dH_1 be the amount of heat taken in by the fluid while Q is passing along a. Let T_2 be the low temperature of the fluid when Q is passing along b, and let dH_2 be the amount of heat given off by the fluid while Q is passing along b.

Consider the reversible cyclic process which is represented by the two portions a and b of the given process curve, together with the isentropic lines between which a and b lie. We will call this cyclic process an elementary cyclic process to distinguish it from the given process. The net result of the elementary cyclic process would be the taking in of the quantity dH_1 of heat at T_1, the conversion of a definite fraction dW of this heat into work and the giving off of the remainder, dH_2, of the heat at temperature T_2. Therefore, according to Arts. 9 and 10 we have

$$\frac{dH_1}{dH_2} = \frac{T_1}{T_2}. \tag{i}$$

Now, dH_1 is heat received by the fluid, and dH_2 is heat given off by the fluid, and one or the other should be considered as negative, say dH_2, then equation (i) should be written:

$$-\frac{dH_1}{dH_2}=\frac{T_1}{T_2}, \qquad \text{(ii)}$$

or

$$\frac{dH_1}{T_1}+\frac{dH_2}{T_2}=0. \qquad \text{(iii)}$$

The whole of the given cyclic process may be broken up into pairs of corresponding parts like a and b, so that the entire heat taken in and given out by the fluid during the given process consists of parts which correspond in pairs like dH_1 and dH_2, and each pair of heat parts satisfies an equation like (iii). Therefore, *the sum of all quotients obtained by dividing the heat taken in by a fluid at each step of any reversible cyclic process by the absolute temperature of the fluid at the step is equal to zero.* That is

$$\Sigma\frac{dH}{T}=0 \qquad (5)$$

for any reversible cyclic process.

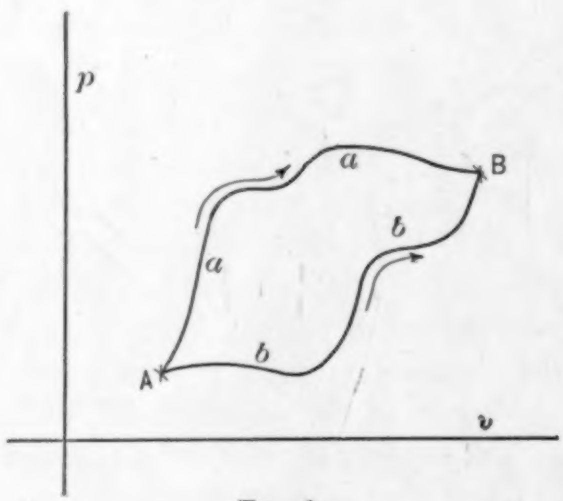

FIG. 2.

Consider two states of thermal equilibrium of a fluid represented by the points A and B, Fig. 2. Let the lines a and b represent any two different reversible processes leading from A to B. Then process a together with process b *reversed* constitute a cyclic process starting from A and returning to A. Therefore the sum $\Sigma\, dH/T$ is equal to zero when it is extended over process a and over process b *reversed.*

Putting this into symbolic form we have:

$$\sum_a\frac{dH}{T}+\sum_{-b}\frac{dH}{T}=0, \qquad \text{(iv)}$$

in which the subscript a indicates that the first summation is extended over process a, and the subscript $-b$ indicates that the second summation is extended over process b *reversed.*

But

$$\sum_{-b}\frac{dH}{T}=-\sum_b\frac{dH}{T}. \qquad \text{(v)}$$

That is, the summation $\Sigma\, dH/T$ extended over the process b *reversed* is equal but opposite in sign to the value of this summation $\Sigma dH/T$ extended over the process b not reversed, that is, when process b leads from state A to state B.

Substituting the value of $\Sigma dH/T$ from equation (v) in equation (iv) we have

$$\sum_a\frac{dH}{T}=\sum_b\frac{dH}{T}. \qquad (6)$$

That is, *the sum* ($\Sigma\, dH/T$) *has the same value for any two, and therefore, for all reversible processes which lead from one given state of thermal equilibrium A to another given state of thermal equilibrium B.*

If the state B is one which can be reached from state A by a sweeping process, then the sum ($\Sigma dH/T$) extended over a reversible process leading from A to B is *positive* in value. Therefore the value of the sum ($\Sigma dH/T$) extended over any reversible process leading from state A to state B of a substance *may be used as a measure of the thermodynamic degeneration* which is associated with the change of the substance from state A to state B. This sum is called the *increase of entropy* of the substance. When the sum ($\Sigma dH/T$) is negative it measures a thermodynamic regeneration and is called a *decrease of entropy.*

Examples.—A gas is allowed to sweep through an orifice and increase in volume from v to V with imperceptible change of temperature. The same gas is then expanded slowly in a cylinder from volume v to volume V without change of temperature. To prevent change of temperature heat must be given to the gas at each step of the expansion (dH positive), and therefore the sum ($\Sigma\, dH/T$) is positive.

A gas is heated at constant volume by the degeneration of work into heat. The same result may be accomplished reversibly by heating the gas slowly on a stove. In this latter process dH is positive at each step and the sum ($\Sigma dH/T$) extended over the slow heating process is positive.

The creation of an external compensating degeneration (decrease of entropy) when the effect of a sweeping process is repaired by a reversible process may be expressed by the entropy change of external substances. Thus in each of the above examples the reversible process involves the taking of heat from external substances so that the sum ($\Sigma dH/T$) is negative as applied to the external changes which are involved in the reversible processes mentioned, or in other words, external substances suffer an increase of entropy when a given substance has its entropy decreased by a reversible process.

In general the thermodynamic degeneration associated with a sweeping process can be represented as an increase of entropy (summation of dH/T as above explained) only by devising a reversible process which produces the same change as the given sweep so far as the substance under consideration is concerned. In the case of steady sweeps, however, it is not *necessary* to devise a reversible process for producing the same result in order to represent the result of a steady sweep as an increase of entropy. The entropy increase which is associated with a steady sweep may be derived from a consideration of the reversible processes which always accompany a steady sweep, using Clausius's summation $\Sigma\, dH/T$, as follows:

Consider the *slow* flow of heat from a body A at temperature T_1 to a body B at temperature T_2. The transfer of heat being slow, the cooling of A and the heating of B are reversible processes, and A and B are at each instant in thermal equilibrium.

While an amount of heat H is transferred the decrease of entropy of body A is $\Sigma dH/T = H/T_1$ and the increase of entropy of body B is $\Sigma\, dH/T = H/T_2$, so that the net increase of entropy due to the steady sweep is $(H/T_2 - H/T_1)$.

Consider a fine wire submerged in a large vessel of water at temperature T, heat being slowly generated in the wire by an electric current. Then the water will be at each instant in thermal equilibrium, that is, the heating of the water will be a reversible process to which Clausius's summation may be applied. Thus, while the water receives an amount of heat W (measured in terms of the work lost in the wire), the value of $\Sigma dW/T$ will be W/T, which is the increase of entropy of the water. In this case there is no decrease of entropy anywhere; so that W/T measures the thermodynamic degeneration involved in the conversion of the work W into heat at temperature T.

Absolute Values of Entropy.—Entropy changes or entropy differences only have real physical significance. However, a certain state of a substance may be arbitrarily chosen as a zero state or reference state and the absolute value of the entropy of the substance in any other given state may be defined as the value of Clausius's summation extended over any reversible process leading from the zero state to the given state. This is equivalent to assigning arbitrarily the value zero to the entropy of the substance in the zero state.

The entropy of a substance in a given state is proportional to the mass of the substance, for doubling the mass will double the value of dH for each step of any reversible process. Entropy is, of course, expressed in *units of heat per degree of temperature.*

Remark.—Equation (5), due to Clausius, was further generalized by Clausius so as to apply in his opinion to cyclic processes which are not reversible, in which case, according to Clausius, equation (5) becomes

$$\Sigma\frac{dH}{T} > 0.$$

This extension of the integral $\Sigma dH/T$ to include sweeping processes is incorrect except in so far as steady sweeps are concerned as explained above.

12. SUMMARY.

The precise idea of temperature is associated with the notion of thermal equilibrium, and the precise idea of temperature has nothing to do with the sensations of hot and cold. The electric arc, for example, is very hot, but it has no temperature.

The error of Clausius in extending his summation to irreversible processes lies in the fact that in general the idea of temperature utterly fails in such cases, and the summation $\Sigma dH/T$ has no meaning whatever. Of course, this summation may always be applied to the reversible changes (when they exist) which take place in the external substances which envelop the substance which is undergoing the irreversible process.

Not only is the precise idea of temperature limited to substances in thermal equilibrium, but it applies only to a finite portion of a substance. It is meaningless to speak of the temperature of a molecule.

There are many cases of steady sweeps, such as thermal conduction in a gas, steady electric discharge through a gas, steady radiation from a hot to a cold region, in which the sweeping substance, be it material or ether, is far from being in thermal equilibrium, although in a permanent or unvarying state. The precise idea of temperature is not applicable to such states. Thus radiation in space has no definite temperature unless the space is enclosed in an envelope which is in thermal equilibrium, in which case the radiation is the normal radiation for the given temperature, and the space occupied by the radiation has, in fact, the same temperature as the adjacent material.

When normal radiation issues from an aperture in an enclosure it becomes attenuated as it travels farther and farther from the aperture, and this attenuated radiation (absorption of medium supposed to be nil), although conforming to a simple law of distribution of energy among its various phases, has not a definite temperature. Neither does a monochromatic beam of light have a definite temperature.

In general, all cases of molecular motion and of ether motion (radiant heat) in which some definite and unvarying function exists expressing the distribution of energy among the various phases of the motion, are to be classed as steady sweeps. In all such cases the precise idea of temperature is inapplicable to the sweeping substance or space. Still, all such processes are amenable to precise and systematic treatment. This systematic treatment always depends upon a knowledge of the function of distribution of energy among the phases, *and the characteristics of the sweeping substance or space are properly described in terms of this function, not in terms of temperature and entropy.*

It is true, however, that a generalized idea of entropy, for example, can be ap-

plied to steadily sweeping substances. Thus Boltzmann's H function, which has a minimum value and closely corresponds to entropy when a gas is in thermal equilibrium, has a definite value for any steady state of a gas other than thermal equilibrium.

Entropy always increases in natural phenomena, and the notion of entropy is, perhaps, much more intimately related to the notion of time than any other physical notion whatever. The notion of entropy seems to me, indeed, to be the very foundation of the notion of time as a physical fact, although the numerical evaluation of time depends, in practice, upon the approximate realization of some of the precise ideas of mechanics.

This intimate relationship of the notions of entropy and time gives very great emphasis to the two propositions A and B in article 7 in which increase of entropy appears as measured by elapsed time.

Heretofore the idea of the increase of entropy associated with a sweeping process has been thought by the ablest writers on thermodynamics, such as Willard Gibbs, to be dependent upon the devising of a reversible process which leads to the same change of state as the given irreversible process. This is, I think, true in regard to sweeping processes in general, but it is not true in regard to steady sweeps.

The characteristic features of irreversible processes are, in my opinion, very clearly suggested by the term sweep and by the special terms simple sweep, trailing sweep and steady sweep, and I urge the adoption of these terms.

W. S. Franklin.

Lehigh University.

METEOROLOGY AT THE BRITISH ASSOCIATION.

Contrary to custom, meteorology took foremost place at the Southport meeting of the British Association. This was largely due to the efforts of Dr. W. N. Shaw, the head of the British Meteorological Office, by whose invitation the International Meteorological Committee met with the British Association for the Advancement of Science and for the first time in England since 1876. The attendance of a majority of the members of the committee justified the innovation, and before going to Southport they were able to meet some representative British men of science at a dinner in London given by Dr. Shaw. Of the seventeen members constituting the International Meteorological Committee, the following ten were present at Southport: the president, Professor Mascart, of Paris; the secretary, Professor Hildebrandsson, of Upsala; Dr. Shaw, of London; Dr. Paulsen, of Copenhagen; Professor Mohn, of Christiania; Dr. Snellen, of Utrecht; General Rykatcheff, of St. Petersburg; Professor Pernter, of Vienna; Professor Hellmann, of Berlin; and Professor Moore of Washington. Although the United States has had a representative in the committee for twelve years, only now, for the first time, was a meeting attended by the chief of the Weather Bureau, indicating the present desire of this country to cooperate in international meteorology. Besides the above, there came for the discussion of meteorological telegraphy, Professor van Bebber from Hamburg and Captain Chaves from the Azores; and of the sub-committee for scientific aeronautics its chairman, Professor Hergesell from Strasburg, M. Teisserenc de Bort from Paris, and the writer. The sessions of the committee lasted five days and the questions considered related principally to details of administration, publication and observation. Of greater scientific interest was an apparatus, shown by Dr. Paulsen, for the collection of atmospheric electricity by the employment of radioactive salts, and a

new hair hygrometer, exhibited by Professor Pernter as superior to the psychrometer. A commission, consisting of Sir Norman Lockyer, Dr. Shaw, Professor Pernter and M. Angot, was appointed to consider the study of the relations of solar physics to meteorology, and it was decided to support the resolutions of the Royal Saxon Academy of Sciences relative to the organization of investigations in atmospheric electricity. After hearing Professor Hergesell's report on the progress in exploring the atmosphere with kites and balloons, the continuation of this work, especially its prosecution in England, was recommended, and the writer's project, to explore the atmosphere above the tropical oceans by means of kites flown from a steamship, received hearty endorsement. It was announced that the committee for scientific aeronautics would meet at St. Petersburg next August, and that the general committee would assemble at Innsbruck in September, 1905. Dr. Snellen resigned from the committee, in consequence of his retirement as director of the meteorological service of the Netherlands, and was succeeded by M. Lancaster, chief of the meteorological service of Belgium. Professor Hellmann, who had recently taken Professor von Bezold's place on the committee, agreed to codify the resolutions that had been adopted at the various meetings since the Vienna Congress of 1873.

In the Physical Section of the British Association meteorology also predominated, the chief topics discussed being the relations of solar activity to meteorology and the exploration of the upper atmosphere. Great interest was manifested in the use of kites for the latter purpose, and this was especially gratifying to the writer, who first advocated the method at the Liverpool meeting of the Association in 1896, and in consequence of the growing interest has since presented annual reports of the results obtained with kites at Blue Hill and on the Atlantic Ocean. The Physical Section was divided into two subsections, and in one of these meteorology was recognized as a distinct branch of physics. Dr. Shaw was chairman of the department of astronomy and meteorology, and it is believed that his introductory address is the first treating exclusively of meteorology which has been given before the Association for many years. The subject was 'Methods of Meteorological Investigation,' and after mentioning the good work accomplished by the several members of the committee and by others, Dr. Shaw declared that meteorology in Great Britain needed the aid of the universities. The topic of simultaneous solar and terrestrial changes was introduced by Sir Norman Lockyer's paper, in which, from a comparison of rainfall and barometric observations in India with solar prominences, the author concluded that the latter are not only the primary factors in the magnetic and atmospheric changes occurring in our sun, but that they are also the instigators of the terrestrial variations. (This paper is reprinted in SCIENCE, pp. 611–623.) Professor Hildebrandsson confirmed the general conclusions of Sir Norman as to the 'surgings' of the barometric pressure, while Professor Hellmann and Dr. Buchan corroborated the coincidence found between rainfall and sunspots, using the data for other years. Father A. L. Cortie, of Stonyhurst, spoke of the recent researches made by Father Sidgreaves, Dr. Chree and himself on the question of the relation between sun spots and terrestrial magnetism. Sir Norman Lockyer, he said, had raised the question as to whether prominences might not supply the place of sun spots in cases where a great magnetic storm was unaccompanied by sun spots. By a series of observations he had made, and by the observations of Father Fenyi,

of Kalocsa, they had come to the conclusion that in no single case could a magnetic storm be with certainty associated with any given prominence, and great disturbances had occurred without any answering swing of the needles. It was, they thought, the general disturbance of the sun and his surroundings which affected the earth's magnetism, and not any particular manifestation of spot or prominence.

The important subject of the investigation of the upper atmosphere was opened for consideration by Mr. W. H. Dines' report of the joint committee of the Association and Meteorological Society on obtaining meteorological observations with kites, which were flown from a steamer off the west coast of Scotland during the past summer. Owing to the slowness of the vessel chartered and the bad weather, the experiments were not very successful, 20 records being obtained in 38 flights, with a maximum height of only 6,000 feet. In his sixth report upon meteorological kite-flying at Blue Hill, the writer stated that during the years 1901–2 the average height reached in the 23 flights was 7,900 feet, with a maximum of 14,060 feet. Some deductions concerning the decrease of temperature in cyclones and anti-cyclones were given and the project of exploring the atmosphere in the tropics by kites flown from a steamer was explained, as is outlined in Science, Vol. XVII., pp. 178–9.

General Rykatcheff described experiments of raising kites in a calm from a Russian warship, steaming twelve knots. M. Teisserenc de Bort traced the circulation of the air around barometric depressions, as evinced by the trajectories of his balloons, and from experiences with kites in Denmark he suggested that the meteorographs carried by them should etch their records on copper, so that these might be preserved in case the instruments fell into the water. Professor Hergesell gave a résumé of the operations of the International Committee for Scientific Aeronautics since its foundation in 1896. For several years monthly ascensions of balloons have been conducted in various parts of Europe, but permanent stations, where kite flights can be made daily, are desired. A kite station was maintained during nine months in Denmark and, since the first of the year, kites, or captive balloons, have been sent up each morning from Berlin and kites less regularly from Hamburg. The monthly observations are collected by Professor Hergesell and published at the expense of the German government. The establishment of an aeronautical observatory in the British Isles would be of great importance for these studies. Professor A. Schuster insisted upon the value of the information that could be derived from kites, and although unmanned balloons can attain the greatest altitudes, he hoped that balloons carrying aeronauts would be included in the program of work, since, with them, samples of air for analysis could be collected from the high strata of the atmosphere and personal observations made of various phenomena. He considered it most important for England to take a proper part in these investigations by placing the Meteorological Office on an altogether different basis, and a discussion of the question at the present time, when so many distinguished foreigners testified as to its importance, appeared appropriate. Professor H. H. Turner expressed the same opinion and declared that he knew of no scheme more deserving of government support than is the exploration of the upper air by means of kites.

Professor Hildebrandsson announced that the discussion of the cloud observations which had been made simultaneously in various parts of the world indicated the following to be the circulation of the atmosphere at different heights: (1) Above the thermic equator and the equa-

torial calms there exists throughout the year a current from the east; (2) above the trades an anti-trade blows from the southwest in the northern hemisphere and from the northwest in the southern; (3) this anti-trade does not pass the polar limits of the trades, but deviates more and more to the right in the northern hemisphere and to the left in the southern, so as to become a current from the west over the barometric maximum of the tropics where it descends to increase the trade; (4) the regions situated at the equatorial limit of the trade join sometimes that of the trade, sometimes that of the equatorial calms, according to the season; (5) the pressure of the air diminishes gradually towards the poles, at least beyond the polar circles; (6) the upper layer of air in the temperate zones flows over the high pressures of the tropics and descends there; (7) the irregularities found at the surface of the earth, especially in the regions of the Asiatic monsoons, generally disappear at the height of the lower or intermediate clouds; (8) it is necessary to abandon completely the idea of a vertical circulation between tropics and poles, hitherto assumed, according to James Thomson and Ferrel.

In the report of the Seismological Commission, presented by Mr. J. Milne, it was inferred from the data collected that the crust of the earth was not more than forty miles thick, the interior having a very high effective rigidity and the nucleus being probably more uniform in its chemical and physical conditions than was usually supposed. The report of the Ben Nevis Observatory Committee, drawn up and read by Dr. A. Buchan, stated that funds privately subscribed would maintain the high- and low-level stations for another year, after which time the permanent support of the government was desired. It was claimed that no pair of stations in the world are so advantageously situated for meteorological investigation and forecasting. Additional papers were by Dr. Buchan on the diurnal variation of temperature in the Levant and its relation to radiation; by Dr. Paulsen on a comparison of the spectrum of nitrogen with that of the aurora; by Dr. W. J. S. Lockyer on the spectra of lightning; by Dr. H. R. Mill on some rainfall problems; by Dr. L. A. Bauer on the magnetic survey of the United States and the earth's total magnetic energy, and by the writer on audibility at Blue Hill as affected by weather conditions.

Upon the recommendation of the council of the Physical Section, the General Committee of the Association passed a resolution that it is desirable to adopt a uniform system of units in meteorology, and another resolution to the effect that the systematic investigation of the upper atmosphere by means of kites and balloons is of great importance. A further appropriation of £50 was voted to Mr. Dines for the continuation of this work with kites.

In conjunction with the meeting of the International Committee, an exhibition of meteorological apparatus, charts and photographs was organized by the Meteorological Office and Society. Many pieces of new apparatus, as well as articles of historic interest, were shown and their study was facilitated by a carefully-prepared descriptive catalogue. The meteorological telegrams received each morning at the London office were repeated to Southport, where they were charted and forecasts made by a member of the staff. These were incorporated in a weather map that was printed and distributed during the afternoon and its close agreement with the map prepared in London from the same data was surprising. It had been announced that Mr. Dines would fly his kites from a steamer at South-

port, but, unfortunately, neither the boat nor the apparatus could be brought from Scotland in time for the experiments. Professor Pernter demonstrated the formation of vortex-rings on a large scale in the open air by firing a conical cannon, such as is used in some parts of Europe to disperse hail-storms. While the efficacy of the process is doubtful, yet in the Southport experiments the smoke-rings issuing from the cannon, which was placed horizontally instead of vertically, could be both seen and heard in their passage through the air for a distance of several hundred feet.

A visit was paid by the International Committee to the Fernley Observatory in Hesketh Park, established by Mr. J. Baxendell, Sr., and now maintained by the borough of Southport. This observatory, which is one of the best equipped in Great Britain, has an auxiliary station, provided with Mr. Dines' anemometers, situated near the coast. Excursions were made to the Stonyhurst College Observatory, near Whalley, Lancashire, and also to the Physical Laboratory of the Owens College in Manchester. About sixty meteorologists sat down to their annual breakfast, in accordance with a custom inaugurated some thirty years ago. The meeting terminated on September 16 with a brilliant banquet to more than one hundred persons, which was given by the mayor of Southport, Mr. Scarisbrick, at his residence, Greaves Hall, in honor of Sir Norman Lockyer, president of the British Association and Professor Mascart, president of the International Meteorological Committee.

A. LAWRENCE ROTCH.

BLUE HILL METEOROLOGICAL OBSERVATORY,
October 30, 1903.

SCIENTIFIC BOOKS.

Manual of Advanced Optics. By C. RIGBORG MANN. Chicago, Scott, Forsemann & Co. 1902. Pp. 193.

As the author states in the preface, this manual is the basis of the advanced laboratory course in optics in the University of Chicago, and represents contributions from various instructors. Naturally, it deals rather extensively with interference and the applications of interference methods.

The opening chapter presents, in a very simple manner, the important but generally neglected theory of the limit of resolution of a telescope. Chapter II. extends this theory to the case of two slit apertures before a lens for both single and double line sources. The experimental illustrations make clear the possibility of measuring the angular size of a source and the angular distance between two line sources, but do not suggest the application of this method to astronomical problems. Reference is not made to Rayleigh's theory of, and experiments with, the central stop. The third chapter, on Fresnel's mirrors, contains diagrams, familiar to all of Professor Michelson's students, illustrating the evolution from the earlier forms of interference apparatus to the modern interferometer. The theory and experiments in this chapter and in the following one on Fresnel's biprism take up seventeen pages of the text, relatively a large part when the grating is treated in eight pages.

Chapters V. and VI. contain Michelson's theory of the interferometer and its elegant applications. The presentation is very clear and the contents complete. The gathering together of material from little-used sources bearing upon the interferometer method, probably the most powerful and yet simple method we know in accurate measurement, makes this manual a valuable one to place in the hands of a student.

The arrangement of the material in Chapters VI. and VII. is out of the ordinary. For in the earlier chapter the author deals with a very modern, complex, perhaps forced, method of analyzing an approximately homogeneous radiation, while in the later chapter he presents the well-known prism method of analyzing a spectrum. The theory of Chapter VII. follows the methods of geometrical optics. Rayleigh's simple method of obtaining the dispersive power of a prism is not given.

The chapters on the plain and concave gratings, considering the space given to other parts of the subject, might have been fuller. The next six chapters contain theory and experiments on polarized light, the rotation of the plane of polarization, the laws of reflection from transparent and metallic surfaces and the spectrophotometer.

Two statements seem to be misleading. On page 90 it is stated that 'the slit in a spectrometer is made infinitely narrow by placing it at an infinite distance by means of a lens.' The meaning, of course, is that the divergence of the rays falling on the prism from one point of the slit is made very small by placing it at the focus of a lens. The angular width of the slit is finite, being equal to the width of the slit divided by the focal length of the lens. Again on page 159 it is stated that 'Ordinary photometers * * * may be used to compare the intensities of the total radiations of two sources.' Authors of texts can not be too careful to point out that the luminous part of the radiations are but a small part of the total energy sent out by a source. Indeed, it is to be regretted that the subject of optics is generally viewed in this limited light, that no mention is made of the instruments, bolometers, radiometers, thermoelements, etc., used in measuring the total energy of sources, and no notice taken of the interesting properties of bodies with regard to radiations other than luminous.

These general criticisms have no large value concerning the special purpose for which the book was prepared. As a manual of advanced optics it is admirable. G. F. Hull.

Dartmouth College.

SCIENTIFIC JOURNALS AND ARTICLES.

The October number of *The American Journal of Anatomy* contains the following articles:

Joseph Marshall Flint: 'The Angiology, Angeogenesis, and Organogenesis of the Submaxillary Gland.'

Richard Mills Pearce: 'The Development of the Islands of Langerhans in the Human Embryo.'

Robert W. Lovett: 'A Contribution to the Study of the Mechanics of the Spine.'

J. Playfair McMurrich: 'The Phylogeny of the Palmar Musculature.'

Bird-Lore for September–October contains articles on 'The Mystery of the Black-billed Cuckoo,' by Gerald H. Thayer, showing that it is a bird of nocturnal habits; on 'A North Dakota Slough,' by A. C. Bent; 'A Tragedy in Nature,' by William Brewster; 'Nesting Habits of Two Flycatchers at Lake Tahoe,' by Anna Head, and on 'How Birds Molt,' by Jonathan Dwight, Jr., one of the best authorities on this much-mooted subject. There is the sixth series of portraits of *Bird-Lore's* advisory councilors and numerous notes, including an interesting article on 'Mortality among Birds in June,' besides book reviews and the reports of the Audubon Societies.

The *Museums Journal* of Great Britain for September contains the address of the president of the Museums Association, F. A. Bather, delivered at the Aberdeen meeting of the association and devoted mainly to the subject of the better arrangement of art museums. A plea is made for smaller exhibition halls and the display of a comparatively small number of objects amid harmonious surroundings. Among the notes is announced the coming extension of the British Museum (the older building) at a cost of £200,000, and the coming publication of the first volume of a catalogue of the books, manuscripts and maps in the possession of the British Museum, of natural history.

SOCIETIES AND ACADEMIES.

AMERICAN PHYSICAL SOCIETY.

The fall meeting of the Physical Society was held at Columbia University on Saturday, October 31. The meeting was well attended and was marked by discussions considerably more extended than have recently been usual at Physical Society meetings. These discussions add so greatly to the interest of such gatherings that the further development of this feature of the meetings is much to be desired.

It was decided to hold the next meeting of the Physical Society in St. Louis during convocation week in connection with the Amer-

ican Association for the Advancement of Science. Since the Physical Society has been one of the affiliated societies of the American Association ever since its organization, this action was to be expected. It is hoped that this meeting of the society in the west will afford an opportunity for some organization there which will bring the same advantages to the physicists of the middle west which the meetings in New York have brought to those in the east.

The first paper, by Dr. P. G. Nutting, was upon the 'Distribution of Motion in a Conducting Gas.' In the experiments described in this paper Dr. Nutting used a thermopile in the form of a thin flat disk. This could be mounted in a vacuum tube in such a way as to present either its flat surface or its edge to the direction of the discharge. At low pressures the temperature indications were quite different in the two cases, since in one case the full bombardment due to moving ions and kathode rays was received on the surface of the pile, while in the other case only the movement across the line of discharge was effective in heating.

A paper on a special type of radioactivity was next presented by Miss Fanny C. Gates. This paper dealt with a peculiarity in the behavior of sulphate of quinine when heated to about 180° C. and then allowed to cool. During the process of cooling the quinine is found to make the air near it conducting; in fact, at first glance the quinine seems to behave for a while much like a radioactive substance. There are strong reasons for believing that the phenomenon is due to some relatively simple chemical change in the quinine, and the case has been cited as an argument in favor of explaining all cases of radioactivity by recognized types of chemical change. Miss Gates finds, however, that the effect produced by quinine obeys entirely different laws from the similar effect produced by radioactive substances. Experimenting with different electromotive forces and with different distances between plates, she found it impossible to produce saturation in the current due to the ionization by quinine. Even with plates only 3 mm. apart at a potential difference of 900 volts no indication of saturation could be observed. Assuming the ionization to be produced by rays emitted by the quinine it was found that these rays are completely absorbed by a thickness of aluminium which would scarcely affect the radiation from radium or uranium by a noticeable amount. The conclusion reached by Miss Gates is that the phenomenon is entirely different from ordinary radioactivity. She inclines to the view that the ionization is due to rays of ultra-violet light produced by the chemical change and absorbed in the immediate neighborhood of the surface.

A short paper by Mr. W. J. Hammer dealt with certain points connected with excited radioactivity. Mr. Hammer mentioned certain experiments which led him to believe that excited radioactivity was more permanent than is generally supposed, and that while it dies out rapidly at first, it finally reaches a nearly permanent value. Mr. Hammer exhibited numerous radiographs taken by himself and referred briefly to experiments by which animals had been killed by action of Becquerel rays. He also suggested the internal use of radioactive substances in the treatment of disease, in instances where it is impracticable to reach the seat of trouble from without. The active rays might be brought to the diseased parts by the use of solutions of radioactive substances or solutions which have been given excited activity.

In a paper on Van der Waals' *a* in alcohol and ether Professor E. H. Hall stated the result of calculations intended to test the validity of certain assumptions connected with the well-known Van der Waals equation. The character of the paper is such as to make it difficult to present the results in a brief abstract.

In the afternoon session W. S. Franklin spoke on the 'Misuse of Physics by Biologists and Engineers.' The object of the paper was to call attention to certain misconceptions of fundamental matters in the subject of thermodynamics which are common among engineers and biologists who have occasion to make applications of physics in their work. Pro-

fessor Franklin's paper led to a discussion of considerable interest.

Dr. Bergen Davis exhibited, in operation, his apparatus in which mechanical rotation is produced by the electrodeless discharge. It will be remembered that the apparatus consists of a little anemometer mounted at the center of a vacuum tube. The discharge in the tube is produced by an oscillating current in a surrounding coil. The motion of the ions constituting this current then produces rotation in the anemometer.

In a second paper by Dr. Davis the theory of 'The Electrodeless Discharge' was considered, the discussion being based upon experiments made upon carbonic acid and helium. It was found that the results in these experiments could be explained upon the assumption that ionization was produced by the impact of ions, these being always present to some extent. The theory developed enabled the mean free path of the ions to be computed. It was found to be 4.4 times the mean free path of the molecules. The result agrees very well with the value 4.3 obtained by J. J. Thomson by entirely different methods. Similar computation showed that an ion must move through a potential of 2.5 volts in order to ionize air. By different methods J. J. Thomson has found about five volts for this same quantity, the agreement in this case being, therefore, less satisfactory.

Ernest Merritt,
Secretary.

AMERICAN MATHEMATICAL SOCIETY.

A regular meeting of the American Mathematical Society was held at Columbia University on Saturday, October 31. The attendance at the two sessions numbered about fifty persons, including nearly forty members of the society. The president of the society, Professor Thomas S. Fiske, occupied the chair. The following persons were elected to membership: Miss Grace C. Alden, Westfield, Mass.; Mr. L. D. Ames, University of Missouri; Professor R. C. Archibald, Ladies' College, Sackville, N. B.; Mr. W. H. Bates, Purdue University; Miss Harriet D. Buckingham, Lexington, Mass.; Miss Louise D. Cummings, Vassar College; Mr. Harry English, Washington, D. C.; Professor G. A. Gibson, Glasgow, Scotland; Miss Mary F. Gould, Everett, Mass.; Dr. O. D. Kellogg, Princeton University; Mr. W. A. Manning, Stanford University; Dr. C. M. Mason, Massachusetts Institute of Technology; Professor Helen A. Merrill, Wellesley College; Mr. E. A. Miller, Massachusetts Institute of Technology; Mr. E. H. Taylor, State Normal School, Charleston, Ill.; Professor Anna L. Van Benschoten, Wells College; Mr. R. E. Wilson, Northwestern University. Nine applications for membership were received. The total membership of the society is now 448, a gain of 48 since January last.

The office of assistant secretary of the society was revived and filled by the appointment of Dr. William Findlay, of Columbia University. A list of nominations for officers and members of the council was prepared and ordered placed on the official ballot for the election which takes place at the annual meeting in December. A committee was appointed to make arrangements for holding the next summer meeting of the society at St. Louis and to cooperate with the committee of the exposition in organizing the mathematical section of the international congresses.

The publication by the society of the courses of lectures delivered at the Boston colloquium by Professors Van Vleck, White and Woods is under consideration. While the society regularly publishes two journals, it could render still greater service to mathematics in several directions if even a small publication fund were at its disposal, its present income from membership dues being barely sufficient to meet its regular outlay in this direction. In view of the great work which the society has accomplished, chiefly at its own expense, it is to be hoped that it may soon receive a modest endowment to enable it to meet its increasing opportunities in a more effective manner.

The following papers were read at the October meeting:

A. S. GALE: 'On three types of surfaces of the third order regarded as double surfaces of translation.'

L. P. EISENHART: 'Surface of Bonnet and their transformations.'

EDWARD KASNER: 'On partial geodesic representation.'

F. N. COLE: 'On the factoring of large numbers.'

E. GOURSAT: 'A simple proof of a theorem in calculus of variations (extract from a letter to W. F. Osgood).'

BURKE SMITH: 'On the deformation of surfaces whose parametric lines form a conjugate system.'

G. A. MILLER: 'On the number of sets of conjugate subgroups.'

ELIJAH SWIFT: 'On the condition that a point transformation of the plane be a projective transformation.'

IDA M. SCHOTTENFELS: 'On the simple groups of order $8!/2$ (preliminary communication).'

IDA M. SCHOTTENFELS: 'The necessary condition that two linear homogeneous differential equations shall have common integrals.'

The American Physical Society was also in session at Columbia University on the same day. The members of the two societies lunched together at the university restaurant. In the evening the members of the Mathematical Society held an informal dinner.

THE annual meeting of the American Mathematical Society will be held at Columbia University, December 28–29. The Chicago section of the society will meet, in conjunction with Section A of the American Association for the Advancement of Science, at St. Louis, December 31–January 1.

F. N. COLE,
Secretary.

DISCUSSION AND CORRESPONDENCE.

THE ST. LOUIS CONGRESS OF ARTS AND SCIENCE.

TO THE EDITOR OF SCIENCE: In the number of SCIENCE for August 28, I occupied considerable space in raising certain questions suggested by Dr. Münsterberg's article on the St. Louis Congress in the May number of the *Atlantic Monthly.* I objected

1. To Dr. Münsterberg's basing the working classification and grouping of the schedule or program of that Congress upon a scheme of philosophical methodology (of which he himself happened to be the author), and

2. To the representation made in the article that the Committee on the Congress had given his methodology an official sanction and endorsement by arranging a program upon its basis.

In what purports to be a reply in SCIENCE for October 30, Dr. Münsterberg elaborately ignores the objection I raised and as elaborately attributes and refutes a position which I neither took nor even suggested. The objection which he attributes to me is upon its face either a matter of minor importance or else is absurd. This is an objection to the actual working classification and grouping adopted for the conduct of the Congress. It does not require two pages of SCIENCE to point out that such an objection is trivial if taken to mean an objection to just this or that number and set of divisions, departments and sections; and absurd if taken to mean objection to any classification and grouping whatsoever. Nor does it require a careful reading of my SCIENCE article to discover that I never entertained such objections.

While I regret that Dr. Münsterberg has raised an irrelevant issue, instead of discussing the matter on its merits, I yet take one consolation from his article. His ignoring the real point of my objection suggests that as a matter of fact the philosophical methodology set forth in such a prominent way in the May *Atlantic* has ceased to have (if it ever had) any bearing upon the actual conduct of the Congress; and that what now exists is just a certain working classification, whose exact merits, as I have just indicated, are a matter of detail and not of principle. In that case, while some explanation would seem to be due the editor and readers of the *Atlantic Monthly,* the scientific men of the country may rest reasonably content.

JOHN DEWEY.

THE UNIVERSITY OF CHICAGO.

RECENT ZOOPALEONTOLOGY.

ADDITIONAL DISCOVERIES IN EGYPT.

Cetacea.—Dr. E. Stromer describes a skull and lower jaw of a new species of *Zeuglodon, Z. Osiris,* from the Middle Eocene of Egypt,

and discusses in detail in two papers* and in an elaborate memoir† the structure and relationships of these animals. He advocates their extremely early origin, holding that even the oldest Creodonta do not give us a sufficiently generalized ancestor, and that we must revert to the Jurassic triconodont animals generally considered as primitive marsupials. The memoir is the most important and exhaustive one which has appeared upon the skull of this aberrant form.

Proboscidea.—Dr. C. W. Andrews‡ continues his important papers on the evolution of the Proboscidea, tracing this line back to *Palæomastodon,* Upper Eocene, and *Mæritherium,* Middle Eocene, a small ungulate with quadritubercular molar teeth, which this author regards as in the direct line leading to the Proboscidea; it shows most interesting relationships to the Sirenia, which tend to connect the two groups.

In this connection may be mentioned a paper by Mr. W. K. Gregory on the 'Adaptive Significance of the Shortening of the Elephant's Skull,'§ in which the mechanical effect of trunk and tusks on the evolution of the skull is worked out in detail.

Other Mammals.—Other African fossils described by Dr. C. W. Andrews‖ include the

* 'Einiges über Bau und Stellung der Zeuglodonten, Sonder-Abdr. a. d. Mai-Protokoll,' *Zeitschr. d. Deutsch. geol. Gesellschaft,* Jahrg., 1903.

'Bericht über eine von den Privatdozenten Dr. Max Blanckenhorn und Dr. Ernst Stromer von Reichenbach ausgeführte Reise nach Aegypten. Einleitung und ein Schädel und Unterkiefer von Zeuglodon Osiris Dames,' Sep.-Abdr. a. d. *Sitzungsberichten d. mathem.-phys. Classe d. kgl. bayer. Akademie d. Wissenschaften,* Bd. XXXII., 1902, Heft III.

† 'Zeuglodon-Reste aus dem Oberen Mitteleochän des Fajûm,' Sep.-Abdr. aus *Beiträge zur Paläontologie und Geologie Osterreich-Ungarns und des Orients,* Band xv., Heft ii. u. iii., Vienna and Leipzig, 1903.

‡ 'On the Evolution of the Proboscidea,' *Proc. Roy. Soc.,* Vol. 71, p. 443.

§ *Bull. Amer. Mus. Nat. Hist.,* Vol. XIX., July 8, 1903, Art. IX., pp. 387–394.

‖ 'Notes on an Expedition to the Fayûm, Egypt, with Descriptions of Some New Mammals,' *Geol. Mag.,* Dec. iv., Vol. X., No. 470, August, 1903.

Arsinoitherium, a large ungulate with a pair of enormous horns on the front part of the skull, and a new hyracoid, *Saghatherium.* In this connection it is noted that 'the presence of five Hyraces in these beds indicates that these animals must at that time have been an important factor in the fauna, and that the comparatively small members of the group now existing are the degenerate descendants of a once important stock.' It is shown that the specialization of the molar teeth in the Hyracoidea was already well marked in the Upper Eocene beds. Of great interest also is the discovery of a large creodont referred to *Pterodon africanus,* of Oligocene age, and of an animal related to *Hyopotamus.* Altogether, the discoveries of Messrs. Beadnell, of the Egyptian Survey, and Andrews, of the British Museum, are the most important features of recent progress in mammalian paleontology.

Of an entirely different nature is the superb memoir entitled 'La Faune Momifiée de l'Ancienne Égypte,' by Messrs. Lortet and Gaillard, recently issued from Lyons. It covers the mummified mammals, birds and fishes of Egypt and includes an exhaustive systematic revision of these types, which have been known over a century but have never hitherto received adequate systematic description.

RECENT DISCOVERIES IN FRANCE.

Lophiodonts.—Professor Ch. Depéret, of Lyons,* has made the welcome discovery of the hitherto unknown skull of *Lophiodon* in the Middle Eocene, *Bartonien* age. He points out that it presents an astonishing resemblance to the skull of the primitive rhinoceroses, while it is remote from the skull of the tapirs. This resemblance agrees with the lophiodont form of the molar teeth, which is substantially intermediate between the tapir and the rhinoceros type.

Creodonts.—Equally welcome is the de-

* 'Sur les caractères crâniens et les affinités des *Lophiodon,*' Ch. Depéret, Extr. des *Comptes Rendus des Séances de l'Académie des Sciences,* t. CXXXIV., p. 1278, 2 June, 1902.

scription by M. Marcellin Boule* (who has now succeeded Professor Gaudry as professor of paleontology in the Natural History Museum of Paris) of a large example of the Lower Eocene creodont *Pachyæna* of the family Mesonychidæ. This is the second example of this family found in France, and it strengthens the proofs of the close relation which existed between northern Europe and North America in the Lower Eocene period. The animal is slightly larger than the *Dissacus saurognathus* of Wortman.

Lower Oligocene Fauna.—Under the title 'Les Vertébrés Oligocènes de Pyrimont-Challonges (Savoie)'† MM. Depéret and H. Douxami contribute an extensive memoir of ninety pages on the Lower Oligocene of Savoy. The rhinoceroses are represented by a new type, *R. asphaltense,* which the authors consider allied to the American *Diceratherium.* It is characterized by a very long skull; the nasals, although separate distally, bear a rudimentary pair of terminal horns; the forefoot retains a reduced fifth digit, whereas the American forms are strictly tridactyl. It is shown that the classic *R. minutus* of Cuvier is exclusively Oligocene. A new genus of tapir, *Paratapirus,* is also described, in which the internal lobes of the superior molars are completely separated. The memoir concludes with a valuable review of localities where a contemporaneous fauna is found in various parts of France.

SOUTH AMERICAN MAMMALS.

Glyptodonts.—Professor Henry F. Osborn has recently described the complete carapace of a new genus of glyptodont, *Glyptotherium,* discovered in Texas by one of the Whitney expeditions under Mr. Gidley. It presents a curious combination of primitive and progressive characters.

Mr. Barnum Brown describes‡ a new genus and species of primitive glyptodont, *Eucinepeltus complicatus,* found on the Rio Gallegos by the American Museum of Natural History expedition of 1898. It is distinguished by the structure of the teeth and by the pitting of the plates on the cephalic shield, characters which are illustrated by a number of figures.

Armadillos.—The 'Reports of the Princeton University Expeditions to Patagonia, 1896–1899, in charge of J. B. Hatcher,' are now appearing rapidly under the editorship of Professor William B. Scott. Volume 5 opens with Part I., No. I., of Scott's Memoir entitled 'Mammalia of the Santa Cruz Beds,' and is devoted to the Dasypoda or armadillos of the Santa Cruz, which are fully described, and richly illustrated in sixteen plates. It is impossible to do justice to this very important memoir, which contains not only much needed systematic revision, but the enunciation of many important biological principles and full anatomical descriptions. The Edentata are regarded as a separate subclass divided into the armadillos, glyptodonts, ground sloths, tree sloths, anteaters, pangolins and aard varks. The Santa Cruz armadillos, as a whole, are very unlike the modern representatives of the suborder, rarely appearing ancestral to existing forms; it is certainly rather disappointing not to find any direct forerunners of the existing South American types. The author concludes that the lines of evolution which ended in recent genera must have taken place in some other region of the South American continent, doubtless the same region as that which gave rise to the true sloths and the anteaters, no trace of the latter two types having yet been found in the Santa Cruz beds. The usual systematic treatment is rendered difficult by the extraordinary variability of these animals. Most of them are of relatively small size. Although of great geological age, fully developed carapaces are found in both the armadillos and glyptodonts. The teeth are devoid of enamel, rootless and tubular, no traces of milk dentition having been observed. Altogether, they present a high degree of specialization, and in some instances, as in the reduction of the dentition in *Stego-*

* 'Le *Pachyæna* de Vaugirard,' *Memoires de la Société Géol. de France,* No. 28, Tome X., fascicule 4.

† 'Mémoires de la Société Paléontologique Suisse,' Vol. XXIX., 1902.

‡ 'A New Species of Fossil Edentate from the Santa Cruz Formation of Patagonia.' *Bull. Amer. Mus. Nat. Hist.,* Vol. XIX., 1903, pp. 453–457.

therium, they are more specialized than any recent armadillos.

MARSUPIALS AND MONOTREMES.

Professor C. F. W. McClure* contributes an exhaustive paper on the venous system of *Didelphys*, based on the examination of very extensive material which shows wide individual variation, partly reversional. In general, the venous system runs back through the monotreme to the sauropsidan or reptilian type, and exhibits profound differences from the venous system of the Placentalia.

Dr. B. Arthur Bensley† contributes a valuable paper in which he demonstrates that the groove on the inner side of the jaw of the Jurassic mammalia erroneously described by Owen and Osborn as a 'mylohyoid groove' is actually a 'meckelian groove,' lodging the Meckelian cartilage. After very extensive comparison of this groove in various types of mammals, he finds it frequently present in the Marsupialia, Edentata and certain Insectivora and Cetacea. It is, however, absent in the Multituberculata; the groove is also wanting in the Echidna, owing perhaps to the degeneration or reduction of the jaw. The paper is fully illustrated.

HORSES AND MAN.

A most interesting recent contribution to the *Comptes Rendus des Séances de l'Académie des Sciences* is by Emile Rivière‡ on the prehistoric figures of horses in the cave de La Mouthe found with figures of the reindeer, antelope, bison, buffalo, mammoth. Although for the most part crude outlines, they all possess a certain artistic value.§ H. F. O.

* 'A Contribution to the Anatomy and Development of the Venous System of *Didelphys marsupialis* (L.),' Part I., Anatomy, *Amer. Jour. Anat.*, Vol. II., No. 3, July 1, 1903, pp. 371–404.

† 'On the Identification of Meckelian and Mylohyoid Grooves in the Jaws of Mesozoic and Recent Mammalia,' *University of Toronto Studies*, No. 3.

‡ 'Les figurations préhistoriques de la grotte de La Mouthe (Dordogne),' *Comptes Rendus des Séances de l'Académie des Sciences*, 28 July, 1902.

§ 'Les Parois gravées et peintes de la Grotte de La Mouthe (Dordogne),' Extr. de 'l'Homme préhistorique,' t. I., fasc. 3, 1903.

THE ENDOWMENT OF APPLIED SCIENCE AT HARVARD UNIVERSITY.

By the will of the late Gordon McKay, of Newport, R. I., inventor of the sewing machine that bears his name, Harvard University receives a very large bequest for applied science, estimated by the daily papers to be 'about $4,000,000 and eventually many millions more.' According to the terms of the will, Harvard University is to receive $1,000,000 when this amount has accumulated from the income, and is thereafter to receive 80 per cent. of the balance of the income after annuities have been paid, and is to receive the entire residue of the estate after the death of the last surviving annuitant.

The portion of the will defining the object of the bequest is as follows:

The net income of said endowment shall be used to promote applied science.

First, by maintaining professorships, workshops, laboratories and collections for any or all of those scientific subjects which have, or may hereafter have, applications useful to man; and

Second, by aiding meritorious and needy students in pursuing those subjects.

Inasmuch as a large part of my life has been devoted to the study and invention of machinery, I instruct the president and fellows to take special care that the great subject of mechanical engineering, in all its branches and in the most comprehensive sense, be thoroughly provided for from my endowment.

I direct that the president and fellows be free to provide from the endowment all grades of instruction in applied science, from the lowest to the highest, and that the instruction provided be kept accessible to pupils who have had no other opportunities of previous education than those which the free public schools afford.

I direct that the salaries attached to the professorships maintained from the endowment be kept liberal, generation after generation, according to the standards of each successive generation, to the end that these professorships may always be attractive to able men and that their effect may be to raise, in

some judicious measure, the general scale of compensation for the teachers of the university.

I direct that the professors supported from this endowment be provided with suitable assistance in their several departments, by the appointment of instructors of lower grades, and of draughtsmen, foremen, mechanics, clerks or assistants, as occasion may require, my desire being that the professors be free to devote themselves to whatever part of the teaching requires the greatest skill and largest experience, and to the advancement of their several subjects.

I direct that the president and fellows be free to erect buildings for the purposes of this endowment, and to purchase sites for the same, but only from the income of the endowment.

I direct that all the equipment required to illustrate teaching or to give students opportunity to practice, whether instruments, diagrams, tools, machines or apparatus, be always kept of the best design and quality, so that no antiquated, superseded, or unserviceable implement or machinery shall ever be retained in the lecture-rooms, workshops or laboratories maintained from the endowment.

Finally, I request that the name Gordon McKay be permanently attached to the professorships, buildings and scholarships or other aids for needy students, which may be established, erected or maintained from the income of this endowment.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND AFFILIATED SOCIETIES.

The American Association for the Advancement of Science will meet at St. Louis during convocation week, beginning on December 28, 1903, under the presidency of the Hon. Carroll D. Wright, U. S. commissioner of labor and president of Clark College. We hope to publish shortly full details in regard to the meeting and the local arrangements.

The American Society of Naturalists will meet at St. Louis during convocation week. The exercises will consist as usual of a lecture followed by a smoker, a business meeting and a discussion on Wednesday afternoon, and a dinner in the evening followed by the address of the president, professor William Trelease, director of the Missouri Botanical Garden.

The sixteenth winter meeting of the Geological Society of America will be held at St. Louis, Mo., probably in a parlor of the Planters Hotel. The meeting will be called to order by President S. F. Emmons at 10 o'clock A.M., on Wednesday, December 30. The meeting of the Cordilleran Section will be held January 1 and 2, 1904, in the Academy of Sciences, San Francisco.

The American Chemical Society will meet in St. Louis on December 28 and 29. The headquarters will be the Southern Hotel, and the meeting place will be the Central High School Building. The retiring address of the President, Dr. John H. Long, will be given, probably, on Wednesday evening at 7:30. Subject: 'Some Problems in Fermentation.'

The American Psychological Association will meet at St. Louis on Tuesday and Wednesday of convocation week under the presidency of Dr. W. L. Bryan, president of the University of Indiana.

The next meeting of the American Philosophical Association will be held at Princeton, N. J., on December 29 and following days. The hospitalities of the meeting and program are also extended to those members of the American Psychological Association who do not meet with their own association in St. Louis.

We hope to publish next week official notices in regard to the other scientific societies meeting during convocation week.

SCIENTIFIC NOTES AND NEWS.

The medical faculty of the University of Buffalo has invited Dr. Samuel J. Meltzer, of New York, to deliver the Harrington lectures for 1903. The subject selected by Dr. Meltzer is 'Edema, a consideration of the physiological and pathological factors concerned in its formation.' The lectures will be delivered in the Medical College, November 30, and December 1, 2 and 3, at 5 P.M.

Mr. Henry Rutgers Marshall, the architect of the library given by Mr. Ralph Voorhees to Rutgers College, and well known for his contributions to psychology, was given the degree of Doctor of Literature on the occasion of the dedication of the library.

Professor Hugo de Vries celebrated the twenty-fifth anniversary of his professorship in the University of Amsterdam on October 25, 1903. On this occasion he was presented with the sum of 4,250 Gulden by his colleagues and admirers in Holland, with the request that this sum be used in prosecuting further researches on mutation in plants. Cooperative experiments in this subject are being carried on in the New York Botanical Garden by Dr. D. T. MacDougal.

Arrangements have been made for a Sigma Xi dinner and address during convocation week at St. Louis. President D. S. Jordan will deliver the address before the society. The society now numbers more than two thousand members in the United States, and a large attendance is expected. Professor A. S. Langsdorf, of Washington University, is secretary of the committee on arrangements.

The Royal Scottish Geographical Society has bestowed honorary membership and its Livingstone gold medal on Commander Robert E. Peary, U.S.N.

It is reported, though perhaps on inadequate authority, that the Nobel prize in physics will be awarded to Mr. G. Marconi; in chemistry to Professor Arrhenius, and in medicine to Professor Finsen.

Professor von Zittel, of Munich, who met with a serious accident recently, is rapidly recovering and hopes to begin his winter semester lectures soon.

Dr. George T. Moore, of the United States Department of Agriculture, is spending a month in Dr. Winogradsky's laboratory at the Imperial Institute for Experimental Medicine, St. Petersburg. He is studying the various soil bacteria, especially those that fix atmospheric nitrogen, and the nitrite and nitrate organisms. Dr. Moore is conducting the investigations of soil bacteria being carried on in the Division of Pathology and Physiology of the Bureau of Plant Industry, and has already accomplished some important work in this field. He will probably not return to Washington before the middle of January.

Dr. E. B. Copeland, A.B. (Stanford, '95), who has been instructor in bionomics at Stanford University for the past two years, will sail this week for Manila to take up his work as chief botanist of the U. S. Philippine commission. Miss Mary Isabel McCracken, A.B. (Stanford, '03), will have charge of Dr. Copeland's work in bionomics.

Professor John W. Toumey, of the faculty of the Yale University Forest School, has been elected director of the Yale botanical garden.

Dr. G. P. Merrill, curator of geology at the U. S. National Museum, has returned from a visit to the petrified forests of Montana.

The daily papers state that Dr. W. G. Tight, president of the University of New Mexico, and Miss Annie S. Peck have returned after explorations in Peru. They failed to reach the summit of Mount Sorata, the highest summit in the Andes.

Professor C. F. Chandler, of Columbia University, gave a lecture before the American Philosophical Society on November 6, his subject being 'The Electro-chemical Industries of Niagara Falls.'

Professor R. E. Dodge, Teachers College, Columbia University, began on the twelfth instant a course of lectures on climate and mankind given at the American Museum of Natural History under the auspices of the Board of Education.

On October 2, the winter course of lectures before the American colony in Munich was opened by Professor Hartzell, his subject being 'Volcanic Phenomena.' He was followed by Professor Fullerton on the sixteenth and thirtieth, his subject being 'Psychic Phenomena.' It is proposed to have lectures on the first and third Fridays of each month during the winter.

Sir William White gave the presidential address before the British Institute of Civil Engineers on November 3.

Commander Robert E. Peary, U.S.N., lec-

tured before the Royal Geographical Society, London, on November 10. He is at present engaged in examining the naval barracks of foreign countries as a member of a commission recently appointed by President Roosevelt.

A MEMORIAL to Professor Joseph Le Conte, has been constructed by the Sierra Club of San Francisco in the Yosemite Valley at a cost of $8,000. It is a building of granite, erected under the walls of Glacier Point. The building is divided into three parts, the main room measuring 28 x 38 feet. Above the main room a Gothic roof rises to the height of thirty-five feet. Inside are a large reading table, wall seats and a large bookcase in which are kept books and papers pertaining to travel and research and maps and papers furnished by the Sierra Club.

THE library of the late Professor Virchow, containing seven thousand volumes has been presented by Mrs. Virchow to the Berlin Medical Society.

THE bronze shield subscribed for by the students of the British Institution of Electrical Engineers was placed on the tomb of Volta, at Camnago, Italy, near Como, on October 4. The shield is mounted on a slab of green marble supported on granite in front of the tomb.

THE position of paleontological draughtsman in the U. S. Geological Survey will be filled by civil service examination on December 8. The salary of this position is $840 or $900 a year.

A CONFERENCE of Eastern hydrographers, called by Mr. F. H. Newell, chief engineer of the hydrographic division of the Geological Survey, was held in Washington from October 28 to 31, inclusive. The following districts and divisions of the work were represented: New England, Mr. N. C. Grover; New York, Mr. Robert E. Horton; Central States, Mr. E. G. Paul; Southern States, Mr. M. R. Hall; Mississippi Valley States, Mr. E. Johnson, Jr.; general inspection, Mr. E. C. Murphy; Washington office, Messrs. G. B. Hollister and John C. Hoyt; hydro-economics, Mr. M. O. Leighton; hydrology, Mr. M. L. Fuller.

ACCORDING to a Reuter telegram from St. Petersburg, dated October 25, the search for Baron Toll, the missing explorer who set out on May 23, 1902, in company with the astronomer M. Seeberg and two Yakuts to explore Bennett Island and who has not been heard of since, still continues. M. Brousnieff, an engineer, who was sent to relieve Baron Toll, arrived in New Siberia with his expedition on March 11, but found nobody on the island. Five days later he set out across the ice in the direction of Bennett Island, but about 30 kilometers from the coast a stretch of open water at least five kilometers broad was encountered, and the expedition was obliged to turn back. No news has been received of the relief party under Lieutenant Koltchak, which was to have endeavored to reach Bennett Island by boat *via* New Siberia, and which was expected to reach its goal last June. There is hardly any prospect of further news being received either from the missing explorer or from the relief expeditions before December, as communication between the islands and the mainland will be interrupted until then.

THE Vienna Academy of Sciences has appointed a committee to study pitchblende, the mineral from which radium is derived. Baron Auer von Welsbach has placed his laboratories at the service of the committee during its researches.

THE Italian Congress of Pathology was held at Florence in October and appointed Milan as the place for the next meeting, which will be held during the spring of 1905. Professors Golgi and Foa were appointed a committee to confer with the German Pathological Society as to whether the approaching congress could be made international.

THE New Zealand Parliament has passed a bill empowering the Governor to introduce after January, 1906, the metric system, which is then to become the only system of weights and measures for the country.

COOPERATIVE arrangements have been made between the United States Geological Survey, through its Hydro-Economic Section, and Professor Chase Palmer, of the Central University of Kentucky, at Danville, for the maintenance of an extended series of chemical ex-

aminations of the water of the principal rivers in that state. This work is carried on under an act of congress authorizing the Geological Survey to determine and report upon the water supplies of the United States. Up to the present time comparatively little has been known either of the quantity and quality of Kentucky waters, or of their availability for use in domestic supply, especially in connection with the larger municipalities of the state. The plan which has recently been put into operation contemplates the periodical examination of the waters of Kentucky River at Jackson, Beattyville, Tyrone, Worthville, Irvine and Frankfort; of Green River at McKinney; of Dix River at Silver Springs and of Salt River at Salvisa. The work is carried on according to the standard methods adopted by the Geological Survey and the chemical profession generally throughout the country, and is under the immediate charge of Mr. M. O. Leighton, hydrographer in charge of the Hydro-economic Section.

UNIVERSITY AND EDUCATIONAL NEWS.

Under the will of Sarah B. Harrison, Yale University is given $100,000, in memory of her brother, the late Gov. Henry B. Harrison, of Connecticut, who for thirteen years was a member of the Yale corporation. The money is given in trust, the income to be used for such purposes as the university shall desire.

A collection of fresh water fishes from different parts of Siberia has recently been received by the Zoological Department of Stanford University. The collection consists of several hundred specimens, and was donated by Mr. James F. Abbott, '99, who is now at the University of Chicago.

The collections and library of the late Albert H. Chester, professor of mineralogy and geology at Rutgers College, have been donated to the institution by his son, Mr. A. H. Chester.

It is said that the medical school which was to have been opened at Constantinople on November 6 has been abandoned and that Professor R. Rieder, who was to have been director, has returned to Bonn.

The Council of the Senate of the University of Cambridge has issued an important recommendation at the instance of the chancellor. The Duke of Devonshire had called their attention to the expediency of modifying the requirements of the university in respect to classical languages and of enlarging the range of modern subjects. It had further frequently been urged upon the council that changes were necessary, owing to the reorganization of secondary education throughout the country and by recent developments in other universities. The council recommended the appointment of a syndicate, with extensive powers of inquiry and discussion, to consider what changes, if any, are desirable in the studies, teaching and examinations of the university.

The *Journal* of the American Medical Association states that the well-known 'Military Medical Academy' at St. Petersburg appropriates annually nearly $800 as a fund for professors in the academy who during the year have published works on their special branches of science. This year it was divided between Professors Bechtereff and Kravkoff, who published manuals respectively on the functions of the brain, and on pharmacology.

Dr. Herbert P. Johnson has been appointed associate professor of bacteriology in the Medical Department of St. Louis University, St. Louis, Mo.

Mr. Franklin D. Barker, formerly head of the Department of Natural Science in Ottawa University, Ottawa, Kans., has been appointed instructor in zoology at the University of Nebraska, Lincoln. He enters at once upon the duties of the new position.

Dr. Howard S. Anders, president of the Pennsylvania Society for the Prevention of Tuberculosis, and lecturer and clinical instructor in physical diagnosis in the Medico-Chirurgical College of Philadelphia, has been made an assistant professor of physical diagnosis in the latter institution.

Dr. Pompeckj, of Munich, has been advanced to professor extraordinary in paleontology and geology.